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Applications of Marine Geodesy

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This paper is a summary of a 1980 research study initiated by the Marine Technology Society and several U.S. government agencies to identify requirements for marine geodetic applications in support of national objectives in ocean science, engineering, and operations over the next two decades. The study established a broad definition of marine geodesy to form a base for marine geodesy's several maritime applications. The study investigated the following areas: bathymetry, hydrography, marine gravity and geophysics, positioning and navigation, plate tectonics/seafloor spreading, ocean surface topography, mean sea level, and tsunamis.

Introduction

Several national studies have indicated in a qualitative way that marine positioning and navigation capabilities are not satisfactory and require improvement. A quantitative analysis of the problem was, however, still lacking. To address the problem, the Marine Geodesy Committee of the Marine Technology Society (MTS), together with several interested federal agencies, held a planning meeting on August 16, 1977, to pursue the concept of a marine geodesy study. It was attended by representatives of the Defense Mapping Agency (DMA), MTS, the National Aeronautics and Space Administration (NASA), the National Oceanic and Atmospheric Administration's (NOAA) National Geodetic Survey and Office of Ocean Engineering, the Office of Naval Research (ONR), the Office of the Oceanographer of the Navy, and the U.S. Coast Guard (USCG). During the course of this and subsequent meetings, the following definition of the term marine geodesy and its areas was established for this study [*Saxena*, 1980]:

> Marine geodesy is the science which defines and establishes control points in and/or on the ocean, and the shape of the ocean including its floor. It includes those maritime activities that depend on determination of position or accurate measurements on, under, and above the ocean surface. The areas covered under this interdisciplinary field, among others, include: bathymetry, positioning (ocean floor and surface), gravity, plate tectonics, seafloor spreading, geoidal undulation, tsunami research, mean sea level, and tidal variation.

Study Objectives

The following study objectives were established: (1) Identify requirements for applications of marine geodesy over the next two decades. (2) Identify any deficiencies in our current technical abilities to meet these requirements. (3) Propose areas of research and development (R&D) to eliminate identified deficiencies. (4) Evaluate the ability of ongoing programs in marine geodesy to handle proposed R&D efforts. (5) Produce a comprehensive report for open distribution as a basis for program development.

The study was conducted in three phases: (1) State-of-the-art papers were prepared by DMA, the U.S. Maritime Administration (MARAD), NOAA, and USCG. Several technical publications were submitted by NASA in lieu of the state-of-the-art paper. (2) Requirement statements were prepared by the study panel and the marine industry. (3) The state-of-the-art and requirement papers were discussed at a 2-day meeting held January 10–11, 1980.

Study Panel

The study panel and their areas of expertise were as follows:

Narendra Saxena, University of Hawaii at Manoa, Chairman (Positioning and Navigation)

Harold Black, APL/Johns Hopkins University (Space Instrumentation)

Carl Bowin, Woods Hole Oceanographic Institution (Marine Gravity, Geophysics, Geology)

Myrl C. Hendershott, Scripps Institution of Oceanography (Ocean Surface Topography, Mean Sea Level, Tidal Variations)

A. George Mourad, Battelle Columbus Laboratories (Economic Aspects)

T. S. Murty, Institute of Ocean Sciences, Sidney, B.C. (Tsunamis)

Fabian C. Polcyn, ERIM/University of Michigan (Shallow Water Hydrography)

Fred Noel Spiess, Scripps Institution of Oceanography (Plate Tectonics, Seafloor Spreading)

Phillip Stutes, John E. Chance Co., Lafayette, La. (Oil and Gas)

Marie Tharp, Oceanographic Cartographer, Piedmont, N.Y. (Bathymetry, Differential Bathymetry (Deep Water))

George A. Zahn, Deep Sea Ventures, Inc. (Ocean Mining)

Narendra Saxena *has been editor-in-chief since 1976 of* Marine Geodesy *and is a founding member of the Tsunami Society. He is the cochairman of the Pacific Congress on Marine Technology to be held in Honolulu April 24–27, 1984. His research activities include satellite geodesy, ocean surveys and mapping, and remote sensing.*

Recommendations

Marine Gravity, Geophysics, and Geology

It has been estimated that where GEOS-3 altimetry is available, the accuracy of the gravity field in the wavelength range of about 200 km can be determined to about 8 mgal. However, to contribute significantly to knowledge of the thickness of oceanic lithosphere, the formation of topographic features, asthenospheric convection, and compositional heterogeneity in the lithosphere and asthenosphere a minimum accuracy of 2 to 5 mgal and resolution of 100 to 1000 km is required.

The present solid-earth geophysical interpretation of the radar-altimeter measurements from satellites is hindered by the lack of detailed knowledge of the depth of the ocean floor over most of the Pacific and southern oceans. The most advanced measurement, that of the direct observation of the geoid, now needs the measurement of ocean depth.

To meet the requirements for the next two decades, the following recommendations are made:

1. Acquire improved accuracies worldwide for (a) satellite orbit determinations; (b) dynamic vehicle position measurements (and continuous); (c) radar altimeter measurements; and (d) satellite-satellite gravity measurements.
2. Launch polar orbiting radar altimeter and gravity missions to improve coverage at high latitudes.
3. Obtain strain measurements in oceanic regions by benchmark monitoring, by implanting instrumentation on the seafloor, and by measurements in Deep Sea Drilling Project drill holes.
4. Encourage ancillary programs for obtaining high quality data for bathymetry, topography, structure from seismic reflection and refraction, heat flow, magnetic field, and surface deformation from leveling and triangulation networks.
5. Encourage geological studies of critical and poorly known regions.

Bathymetry, Differential Bathymetry (Deep Ocean)

Two potential systems of obtaining bathymetric information are multibeam bathymetric sonar and sidescan (or side-looking) sonar. The former system provides quantitative information; the latter provides qualitative information.

The first nonmilitary version of a multibeam (wide swath) bathymetric sonar system—called SEA BEAM—has been in service since May 1977. Due to its angular resolution of 2.7°, swath width approximately equal to 78% of the depth, and maximum operating depth of 11,000 m, SEA BEAM may become the deep-water bathymetric system. Initial tests indicate an accuracy of ±2 m in water depths of 4750 m. Further testing of SEA BEAM is needed.

Although sidescan sonar provides basically a qualitative picture, it can also measure depth by using an appropriate mathematical model, i.e., using stereoscopic sidescan sonar images. Swath Map, a new sidescan sonar system, should be tested for accuracy of depth obtained from mathematical modeling of stereoscopic sonar images.

A precise differential bathymetric survey (±1 m) in the tsunamigenic earthquake area must be conducted for computing the tsunami energy based on an estimation of the elevation of the ocean bottom before and immediately after the earthquake.

To prepare for future marine mining needs, mapping and sampling of economic areas such as manganese nodule deposits must be extended.

To prepare for year-round commercial submarine tanker oil transport from the Arctic, under-ice bathymetry is needed over the routes from Prudhoe Bay under the ice cap to the U.S. east coast to provide a series of good quality (±10 m) strip charts.

Shallow-Water Hydrography

To facilitate greater offshore exploration activities, improved bathymetry of resource-rich coastal waters (especially the U.S. east coast and Gulf of Mexico) is required. There have been a large number of ship groundings owing to depths that were shallower than charted. It would be desirable to have more precise bathymetric maps (accuracy to ±0.3 m) prior to further leasing.

We recommend an early evaluation of various shallow-water survey techniques for coverage, maximum depth, and cost. This evaluation should include the Bathymetric Swath Survey System, photobathymetry, sidescan sonar systems, Airborn Laser Hydrography, and Satellite Hydrography. These evaluations are an industry requirement for technology transfer; to be realistic they should be undertaken both as in-house studies by federal agencies and as independent, outside (university or industry) studies.

The current trend to digitize the bathymetric data should be continued, and NOAA, in conjunction with other concerned agencies and the growing community of industrial and academic users, should review the usefulness of the data's format.

Positioning and Navigation

All positioning requirements are for underwater points, mostly on the ocean bottom.

Offshore Positioning

Due to the continued increase in offshore exploration activities, we recommend the concept of an offshore cadastral survey. To acquire the desired offshore cadastral survey accuracy of ±5 m, techniques and instruments must be developed that will also be required to determine positions of large oil wells to within ±5 m and to recover them in case of blow-outs.

Deep Ocean

Techniques and instruments must be developed to achieve the desired accuracies ranging from ±1 m to ±10 m in deep-ocean work in the following fields:

Mining: ±10 m
Territorial boundary (22 km): ±5 m
Ocean-bottom control net: ±1 m

Permanent stations should be established on at least 10% of the ocean floor of interest for national needs in engineering, research, and operations, with an accuracy of ±1 m. There should also be a study of various types of benchmarks to be used for defining permanent stations.

Surface and Under-Ice Navigation

The complete availability of today's transit satellite navigation system and tomorrow's GPS satellite system is crucial to the majority of marine geodesy programs and requirements. We recognize that these systems are designed and funded by the U.S. Department of Defense (DOD) to meet national defense needs, and such applications are their primary reason for existence. At present there is no institutional recognition of the secondary fact that these systems are a national asset and are vital in current and future research and exploitation of the oceans.

We strongly recommend the consideration of civil marine geodesy needs in secondary uses of navigation satellites. Since formal DOD/Department of Transportation (DOT) coordination is now established for radio navigation (as described in the Federal Radio Navigation Plan), it would seem logical to make the DOT Navigation Council or one of its subunits the point of contact for national civil use of these satellites.

We also urge the creation of a program to determine the feasibility of under-ice navigation of merchant bulk-carrier submarines.

Plate Tectonic and Seafloor Spreading

Experimental studies could contribute to the explanation of some of the problems related to geodynamics, such as the correlation of plate movements with earthquake predictions; however, no systems are in use to make these measurements in the ocean. Since the relative movements of the plates range from 2 to 20 cm/yr, precision transponders could measure the movement rate to the desired accuracy of 1 cm/yr at the spreading center. Since appropriate designs for these precision transponders exist, they should be built and tested at deep sea, and appropriate software for the data must be developed.

Ocean Surface Topography, Mean Sea Level, Tidal Variations

The panel strongly recommends the resolutions of the International Symposium on Interaction of Marine Geodesy and Ocean Dynamics held in Miami in January 1979:

> Recognizing the value of global and regional satellite techniques for the solution of oceanographic and geodetic problems, we recommend that a state-of-the-art satellite altimeter with at least ±10 cm accuracy and with at least ±10 cm orbital tracking, be launched immediately.

Article (cont. on p. 410)

Forum

Methane in Association With Seismic Activity

It has been hypothesized that upward movement of vast quantities of methane gas from the earth's mantle is a causative agent of earthquakes [*Gold*, 1979]. Much of this hypothesis rests on accounts of flames and/or loud, booming noises ("brontides") accompanying seismic events, possibly caused by the explosive release of this "primordial" methane to the atmosphere [*Claflin-Chalton and MacDonald*, 1978; *Gold and Soter*, 1979]. This speculation has generated much controversy because it implies a nonbiological origin for petroleum, as well as the presence of an abundant, potentially harvestable supply of energy in the mantle [e.g., *Nature, 1982; Eos*, 1983]. However, there is a paucity of experimental data to either support or contradict this hypothesis. Because of this continuing, unresolved controversy, I have decided to publish some observations made several years ago with respect to methane emanations during an earthquake that struck near Mammoth Lakes, Calif. [*Oremland*, 1979]. It is of significance that this region lies in close proximity to Owens Valley where accounts exist of flames emanating from the ground during the 1872 earthquake [*Claflin-Chalton and MacDonald*, 1978; *Gold*, 1979].

One possible test of Gold's hypothesis would be the demonstration that dramatic releases of methane frequently accompany seismic activity. Although it does not necessarily follow that methane released during seismic events is of primordial origin (e.g., biogenic or thermogenic methane entrapped near the surface could be released by strong earth movements), the consistent presence or absence of unusually large plumes of methane in association with earthquakes would either lend support to or contradict the hypothesis, respectively. An earthquake of 5.7 magnitude (Richter) struck about 30 km southeast of Mammoth Lakes, California, at 9:45 A.M. on October 4, 1978 (for details see *Savage and Clark*, [1982]). The depth of the epicenter was 13.6 km [R. Corkerhan, personal communication, 1983]. The initial shock lasted several seconds, and a series of aftershocks of diminished intensity occurred for several hours thereafter. Eyewitnesses at Hot Creek, a geothermal stream having several fumaroles, reported the sudden release of large quantities of steam and gases at the time of the first shock. These emanations were of sufficient magnitude to panic the few bathers present, and park officials immediately closed the area. There were no observations of flames exiting the ground. Because I had established a record of the methane content of some of the Hot Creek gas seeps 57 days prior to the earthquake, and because the creek was studied previously with respect to its chemistry and gaseous emanations [*Mariner and Wiley*, 1974], it was possible to determine if any dramatic increase in the methane content of these geothermal gases occurred soon after the initial shock of this seismic event.

Table 1 lists the methane concentrations of two proximate gas seeps (A and B) and two large fumaroles (C and D). Seep A consisted of a slow trickle of bubbles (about 25 cc/min) emanating from warm sediments (50°C) located near the stream bank (water depth about 10 cm). Seep B was located about 1 m away in slightly deeper water (depth about 25 cm), had a faster gas flow rate (about 100 cc/min), and emanated from a more rocky bottom than seep A (sediment temperature = 50°C at seep B). Methane concentrations in the gases from both seeps were low and actually decreased somewhat with the arrival of the earthquake. These methane values are in agreement with the data of *Mariner and Wiley* [1974]. Fumaroles C and D were located about 50 and 75 m, respectively, away from seep A and on the opposite stream bank. Prior to the quake, they were senescent and demonstrated minimal gas ebulition (they were not sampled). However, after the first shock and for several subsequent days they violently

TABLE 1. Methane Concentration in Gases From Hot Creek Seeps (A and B) and Fumaroles (C and D)

	Percent Methane in Gas Phase		
Site	Sept. 17, 1978	Oct. 4, 1078	Oct. 9, 1978
A	0.16	0.12	0.12
B	0.07	0.06	ND
C	ND	0.01	0.01
D	ND	0.01	0.01

Gases were collected by displacement of water in a capped funnel. The collected gases (50 cc) were next drawn up into a syringe, and the contents were injected into sealed, vented serum vials (volume = 3 cc). Analyses were performed within 3 hours of sample collection. Collection of gases on Oct. 4, 1978, were made within 3 hours after the first shock. Samples were analyzed on a Varian series 1400 flame ionization gas chromatograph equipped with a Porapak Q column (305 × 0.64 cm; N_2 carrier flow = 30 cc/min). Limit of detection was about 0.0003%. ND = not determined.

extruded gas bubbles and silt. Fumarole C even spawned a 8 m high water geyser as a consequence of the earthquake. Therefore, new materials were being brought to the surface; however, the methane content of gases emanating from these hot fumaroles (water temperature = 82°C) was about an order of magnitude lower than that of the bubbles exiting the cooler seeps (Table 1). None of the gases collected was combustible.

The higher methane concentrations of the gases at seeps A and B were due to the presence of methanogenic bacteria in the warm and reducing sediments (they had an H_2S odor) surrounding the seeps. Thermophilic methanogenic activity is a common occurrence in hot springs [e.g., *Ward*, 1978], and anaerobic incubation of sediments taken near the seeps demonstrated abundant biological methane production at 62°C (Figure 1). Methanogenesis was blocked by addition of chloroform (Figure 1), an inhibitor of methanogenic

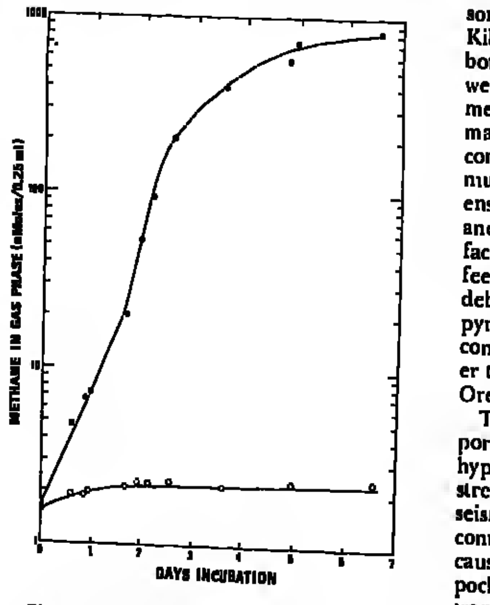

Fig. 1. Methanogenesis in Hot Creek sediments incubated statically in the dark at 62°C. Sediments were collected with a plastic core liner (upper 5 cm of sediment) from a warm (54°C) fumarole located near seeps A and B; 50 cc of sediment were placed into 250 cc Erlenmeyer flasks that contained 75 ml of fumarole water. Flasks were gassed with N_2 for 5 min and then sealed with black rubber stoppers. Open circles, flask containing 0.1 ml of chloroform; closed circles, uninhibited flask. Final methane levels achieved in the uninhibited flask (412 µmoles) corresponds to about 8% of the gas phase volume. Addition of 50 cc of H_2 to another uninhibited flask caused an immediate, seventeenfold stimulation of methane production rates (data not shown).

bacteria [*Bauchop*, 1967], and, in addition, methane production rates were stimulated seventeenfold by addition of hydrogen to the sediments (data not shown). The high temperatures at fumaroles C and D exceed the physiological range of most thermophilic methanogens [*Zeikus and Wolfe*, 1972; *Ward*, 1978], and therefore the lower methane content of the fumarole gases was probably a consequence of these organisms being absent from those environments. Further evidence for the active presence of methanogenic bacteria near the seeps but not the fumaroles can be inferred from the presence of traces of hydrogen in the fumarole gases (0.03–0.07%) but not in the seep gases. Hydrogen is commonly associated with geothermal gases [*Lyon*, 1974], and because it is a common substrate of methanogenic bacteria, it would be removed from gases that transit sediments harboring an active flora of these organisms.

It is therefore evident that increases in the methane content of geothermal gases did not accompany this earthquake and that methane remained a minor component of the gases. Furthermore, increases of methane were not observed during a 1974 eruption of the Kilauea volcano in Hawaii, and concentrations in collected gases remained below 1.4 ppm (R. Lamontagne, personal communication, 1983). It has been argued that one might not observe liberation of methane in volcanic regions if mineral-catalyzed oxidation of methane to carbon dioxide occurred [*Gold*, 1979]. However, experimental evidence does not support this contention [*Sackett and Chung*, 1979]. Furthermore, the oxidation reaction envisaged would have to operate at near 100% efficiency to account for the low methane values observed in Hot Creek and Kilauea, a feat that is difficult to achieve for a vast volume of methane quickly transiting a hot mineral region during an earthquake. Finally, as noted at the outset, Hot Creek lies in proximity to the region where accounts of flames escaping the earth were recorded during the Owens Valley earthquake of 1872 and were cited as supportive evidence for the methane "deep gas" hypothesis [*Gold*, 1979].

It should be noted, however, that methane can be an abundant component (i.e., >40%) of the gases of mud volcanos [*Reitsema*, 1979]. In addition, significant levels of methane (about 2.5%) were observed in some of the gases collected during a 1977 Kilauea eruption [*Graeber et al.*, 1979]. In both cases, however, the investigators were able to attribute the source of the methane to pyrolysis of buried organic matter. I have observed a high methane content (about 11%) in gases exiting the mud-flow debris region on Mount St. Helens. However, the presence of both ethane and propane in the gas as well as the fact that the site was located on top of 600 feet of hot, recently buried organic-rich debris lends further credence to a shallow pyrolytic origin (with perhaps a biogenic contribution as well) for the methane rather than a deep "primordial" one [R. S. Oremland, unpublished data, 1983].

The observations presented in this report contradict the methane "deep gas" hypothesis of *Gold* [1970]. It must be stressed that any gases released during seismic events or along rift zones may become relatively enriched in methane because of contributions made by liberated pockets of ancient or recent methane entrapped within the crust. This gas may have been formed by biogenic (as in the case of Hot Creek) or thermogenic mechanisms occurring within the crust. Thus, observations of isotopically heavy methane ($\delta^{13}CH_4$ = −20 to −15 per mil) in association with plumes of ^3He emanating geothermal regions [*Welhan and Craig*, 1979; *Gutsalo*, 1980; *Lupton and Craig*, 1981; *Welhan et al.*, 1981] does not prove a mantle origin for the methane because the gas may have been "stripped" out of the crust with upward movement of ^3He. Furthermore, identification of sources of methane that are based primarily on carbon isotopic composition of the gas can be clouded by the activities of methylotrophic bacteria which can enhance the ^{13}C component of the methane [*Silverman and Oyama*, 1968; *Barker and Fritz*, 1981; *Coleman et al.*, 1981] and give it a thermogenic character. Such data, when used to identify sources of "primordial" methane, should be interpreted with caution.

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Also recognizing that improved satellite techniques can resolve many small-scale oceanographic problems, we recommend the development of space instrumentation with at least an order of magnitude improvement in accuracy and the incorporation in the space systems of ancillary instruments to measure such phenomena as sea state, sea surface temperature, ice, salinity, and color, and further recommend that these space programs be undertaken on regional and global scales on a continuous basis.

Finally, recognizing the need for additional surface and subsurface measurements in solving oceanographic and geodetic problems, we recommend that an ocean monitoring system and data handling facility be developed and implemented concurrently with the satellite system.

Tsunamis

To improve the reliability of tsunami prediction, we recommend development of a deep-water system to measure tsunami wave height in real time. This system would provide a supplemental parameter to the tsunami warning system and would be of immense use if a failure of the tide gauge systems occurs, as it did in the December 1979 tsunami.

Conclusion

After the technical recommendations, the panel urged that a study be made to investigate the economic benefit-to-cost ratio for each specific recommendation, and concluded with the following proposal:

Since marine geodetic programs are distributed within several federal agencies, which due to duplication of programs waste user's time to locate a right agency for obtaining information, we strongly recommend that a dynamic group be formed to conduct marine geodetic program direction; this group should be within one federal agency and responsive to all ocean applications programs. This group should be advised by all segments of the involved scientific and user community in the tradition of the Office of Naval Research and the National Aeronautical and Space Administration.

Acknowledgments

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News

Volcanic Sulfur Dynamics

Gaseous sulfur in the aerosol clouds produced by the eruptions of Mount St. Helens and El Chichón is the current focus of research on the effects of matter injected into the atmosphere by volcanoes. Recent research shows that new particles of sulfuric acid are formed up to 3 months after an eruption and that these particles can continue to grow for more than half a year following an eruption. These sulfuric acid particles may alter the earth's climate by interfering with the transmission of radiation from the sun into the lower atmosphere and of infrared radiation from earth back out to space. Furthermore, evidence published last month claims that sulfur emissions during noneruptive phases may be the main source of volcanic sulfur in the atmosphere.

Although effects of sulfuric acid are minimal in the troposphere (which extends to approximately 16 km above the earth at the equator and to 9 km at the two poles), it causes measurable changes in the flow of radiation in the stratosphere (the next major layer above the earth, ranging in thickness from 13 km at the equator to 50 km at the poles). Ongoing research aims to assess the complete impact of sulfur and its derivatives on the chemistry of the atmosphere. According to M. Patrick McCormick of the National Aeronautics and Space Administration (NASA), the May 1980 eruption of Mount St. Helens and the April 1982 eruption of El Chichón provided researchers with an experiment in nature at a time when there is sound technology with which to conduct investigations. The scale of this experiment is suggested by the volume of sulfur involved: The stratosphere was injected with approximately 7.5×10^7 kg of sulfur by the 1980 Mount St. Helens eruption (*Eos*, August 10, 1982, p. 601), and the 1982 El Chichón eruption infused an even greater amount, recent work shows.

Sulfuric acid (H_2SO_4) is the product that directly interferes with solar radiation. The amount of atmospheric H_2SO_4 formed from an injection of sulfur is a function of the sulfur's residence time in the atmosphere and the oxidation and hydration rates it undergoes there.

Although the exact conversion rate of sulfur to sulfuric acid is still under investigation, it is more rapid in the stratosphere than in the troposphere because of higher photochemical activity caused by stronger solar radiation at that level of the atmosphere. The oxidation process leading from sulfur to sulfur trioxide (S, SO, SO_2, SO_3) and the subsequent hydration to H_2SO_4 varies with the availability of water vapor, which fluctuates in different regions over the earth. (Most volcanic sulfur is injected into the atmosphere as sulfur dioxide.)

In 1981, A. S. Kabanov and S. S. Khmelevtsov, of the Experimental Meteorology Institute in the USSR, speculated on the mechanism of sulfate aerosol formation in the stratosphere. They proposed that droplets grow when sulfuric acid molecules adhere to existing water droplets, formed as stratospheric water vapor passes into the liquid phase.

By virtue of vertical mixing and water precipitation, the troposphere is cleansed of sulfur products much more quickly than the stratosphere. The residence time of sulfur products is measured in days to weeks in the troposphere, whereas it is 1–3 years in the stratosphere.

D. J. Hofmann and J. M. Rosen, reporting in *Geophysical Research Letters* in April 1983 on the amount and mass of sulfuric acid aerosol produced by El Chichón, concluded that new particles of sulfuric acid were formed for about 3 months after the eruption. When particle formation ceased, though, particle growth was evident 7 months after the eruption. Their observations, made with three balloon-borne optical particle counters, revealed two layers of aerosol particles in the stratosphere. The higher layer, located at 25 km, consisted of 80% sulfuric acid, while the lower layer, hovering around 18 km, consisted of 60–65% sulfuric acid, estimate the University of Wyoming scientists. Data also indicated possible partial depletion of water at 26 km because of the conversion of gaseous sulfur to sulfuric acid.

Foremost among the instruments used to measure aerosol dispersion is the light detection and ranging (LIDAR) remote sensing system. The device operates by shining light into space. Backscattering of the lightwaves by particles in the atmosphere produces an echo that is then compared with atmospheric heights, and a measure of the dispersion is then calculated. While unable to distinguish between specific compounds, LIDAR can determine the position and relative size of an aerosol cloud of volcanic origin.

Arlin Krueger, also of NASA, said that systems used to measure sulfur dioxide include the Total Ozone Mapping Spectrometer (TOMS) number 7 and the Solar Backscatter Ultra Violet (SBUV), both on the Nimbus-7 satellite. Although these instruments were designed to measure ozone, they can distinguish sulfur dioxide from ozone by the difference in the wavelengths of the radiative energy the compounds absorb. According to Krueger, the volume of sulfur dioxide measured by the systems employed by NASA is less than is implied by the size of the aerosol cloud; there may be a large, undetected volume of sulfur bound in another form, he said.

Following the 1980 eruption of Mount St. Helens, Alan R. Bandy of Drexel University and his colleagues embarked on project RAVE (Research on Atmospheric Volcanic Emissions), an effort by NASA and university scientists to investigate the detailed chemical nature of volcanic plumes. Research conducted by the team using the LIDAR system, among others, is expected to expand the basis for diagnosing the major processes in volcanism.

In a 1982 paper, the team stressed that "better estimates of the magnitude and variability of volcanic emissions are required if the importance of this natural source of atmospheric constituents and the resulting effect on atmospheric chemistry and burdens of species are to be elucidated." An important result of a RAVE experiment (conducted by repeatedly traversing the volcanic plume) reported in 1982 was the estimate of sulfur dioxide flux from Mount St. Helens as 9×10^4 kg/day on September 22, 1980.

The use of direct measurements of volcanically injected sulfur and a proposed classification of volcanic activity, including eruptive and noneruptive phases, are the main advantages of a new model that assesses atmospheric sulfur contributed by volcanoes, according to a paper in the April 20 *Journal of Geophysical Research*. H. Berresheim and W. Jaeschke of the Center for Environmental Protection at the J. W. Goethe-University, Frankfurt/Main, Federal Republic of Germany, argue in their paper that emissions of sulfur during noneruptive phases, previously neglected by researchers, are the main source of the volcanic sulfur in the atmosphere.

In the same issue, the University of Wyoming's Rosen and Hofmann report on the newly discovered quasiannual variation of concentrations of condensation nuclei. Condensation nuclei are liquid or solid atmospheric particles that instigate the condensation of vapors into aerosols. Although the team concludes that there is no single explanation for the variance of condensation nuclei concentration, it speculates that sulfuric acid resulting from recent eruptions may play a role. Rosen and Hofmann say that study of condensation nuclei, thought to be the link between precursor gases and aerosol formation, will aid in developing predictive models and understanding stratospheric aerosol chemistry.—*MEG*

EOS

Transactions, American Geophysical Union
The Weekly Newspaper of Geophysics

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Cover. Large gas and ash eruption of Sakurajima Volcano near Kagoshima in Kyushu, Japan, on September 13, 1981. A series of powerful eruptions that day produced extensive ashfall and measured flux of SO_2 of greater than 11,000 tons per day. Sakurajima has been almost continuously active since 1966; extensive measures have been taken to monitor its activity and preparations made for rapid evacuation of local residents. (Photograph courtesy of Stanley N. Williams, Department of Earth Sciences, Dartmouth College, Hanover, N.H.)

Would you like to be on the cover of *Eos*? Do you have photographs (preferably black and white) of geophysical phenomena? Or of unusual experimental results or graphs and charts with both aesthetic charm and scientific interest? *Eos* would like to consider them for publication on the cover. Send your favorite photo with a short (50-200 words) explanation that can serve as a caption, or you may submit a more extensive news item or even a short article to accompany a proposed cover. Captions will be by-lined. If the material has been previously published, please supply a copyright release from the original publisher. Send to *Eos* Cover, AGU Publications Office, 2000 Florida Avenue, N.W., Washington, DC 20009.

Pioneer 10 Leaves Solar System

The National Aeronautical and Space Administration's (NASA) unmanned spacecraft, Pioneer 10, was expected to leave the outer reaches of our solar system on June 13, 1983. (The division between the solar system and outer space is defined as the edge of the sheath of influence of the solar wind; this sheath is called the heliosphere.) On its way to space beyond our solar system, Pioneer 10 will pass close enough to Neptune and Uranus to obtain data which may be useful in determining whether or not "Planet X" exists. Planet X is the hypothetical cause of Neptune's and Uranus' perturbed motion, so far unexplained by earth observation. In addition, as it leaves the heliosphere, scientists hope Pioneer 10 will map the apex of the solar wind teardrop.

Pioneer 10, launched on March 2, 1972, was intended to last for about 2 years. When Pioneer 10 leaves our solar system in June and heads into interstellar space, NASA will celebrate its success. Ceremonies will be held in the Capitol, the Ames Research Center where the Pioneer 10 project is being manned, and at TRW in southern California where the spacecraft was built.

Now the spacecraft is nearly 2.8 billion miles from the sun. Tracking data are being obtained regularly and will continue to be received, even when it is twice as far from earth as it is now.—*PMB*

Combating Illiteracy

A science course for nonscientists at Columbia University's Columbia College that was created in 1981 as an experiment to combat "the national crisis of scientific illiteracy" has received major new foundation support and has achieved a permanent place in the college's curriculum.

The course, The Theory and Practice of Science, has received a $240,000 grant from the Andrew W. Mellon Foundation, according to Robert E. Pollack, college dean, professor of biological sciences, and originator of the course. The grant will be used for the preparation and publication in 1985 of a textbook, titled *The Scientific Experience*, which will permit the course to be taught at other schools around the country.

The course is designed to expose students to the way in which scientists think and reach conclusions about the physical world, rather than to teach them the substance of only one discipline. The course "is unique," Pollack said. "It is not a history or philosophy of science, but a study of pure science, to show what scientists think is elegant about their subject." Pollack teaches the course with Herbert Goldstein, professor of applied physics and nuclear engineering, and Jonathan Gross, professor of mathematical statistics and computer science. Funds from the Mellon grant will enable the addition of four other faculty members and the addition of a second section of the course in the 1983–1984 academic year. More sections are planned for future years, Pollack noted. The four faculty joining the original core are Samuel Eilenberg, University Professor Emeritus; Darcy Kelley, associate professor of biology; David Helfand, associate professor of physics; and Robert Crease, philosophy instructor.

The course, which began with 15 students and funding from the Exxon Education Foundation and an anonymous alumnus, doubled in size in the 1982–1983 academic year with a grant from the Atlantic Richfield Foundation.

NEXRAD Negotiations

Two firms have been selected for negotiation for preproduction models of NEXRAD, the next generation weather radar system that aims to improve severe weather forecasting. The 40-month, cost-plus-fixed-fee con-

News (cont. on p. 412)

News (cont. from p. 411)

tracts, each valued at $20 million, were awarded to Raytheon Co. of Wyland, Mass., and to Sperry Corp. of Great Neck, N.Y., according to the National Oceanic and Atmospheric Administration (NOAA).

The contract awards represent the second of four phases in the 10-year process of the development and deployment of a national weather radar system to replace existing but aging units. One of the companies will be selected in late 1986 for a contract for limited production of the radar units. Full production and installation of the first operational units are expected by early 1988.

NEXRAD is a joint effort of the Commerce, Defense, and Transportation departments to develop an advanced radar with Doppler capabilities that meet the needs of NOAA's National Weather Service, the Federal Aviation Administration, and the U.S. military.

Geophysicists

The following AGU members were recently elected to membership in the National Academy of Sciences: ***Thomas M. Donahue***, chairman of the department of atmospheric and oceanic science at the University of Michigan; ***Wilford R. Gardner***, chairman of soils, water, and engineering at the University of Arizona; ***Stanley R. Hart***, professor of geochemistry at the Massachusetts Institute of Technology; ***Jerome Namias***, resident meteorologist at the Scripps Institution of Oceanography; and ***Norman F. Ness***, chief of the laboratory for extraterrestrial physics at NASA's Goddard Space Flight Center. In addition, ***Ikuo Kushiro***, a staff member at the Carnegie Institution of Washington's Geophysical Laboratory and professor of petrology at the University of Tokyo, was elected a foreign associate of the Academy. ***William A. Nierenberg***, director of the Scripps Institution of Oceanography, was elected to the National Academy of Engineering. He was cited for outstanding engineering and scientific contributions in the field of oceanography, with particular application to deep ocean operations.

Wallace Broecker, at the Lamont-Doherty Geological Observatory, ***Warren Hamilton***, at the U.S. Geological Survey, and ***Patrick Hurley***, at the Massachusetts Institute of Technology, were elected honorary members of the Geological Society of London.

Cesare Emiliani, chairman of the University of Miami's geology department and director of the undergraduate marine science program, has been awarded the Vega Medal by the Swedish Geographic Society in recognition of his isotopic analysis of deep-sea sediments that he used to study the ice ages. Previous recipients include oceanographer ***H. U. Sverdrup*** (1930) and geophysicist ***Maurice Ewing*** (1963).

Hollis D. Hedberg, Princeton University emeritus professor of geology, received the American Geological Institute's Medal in Honor of ***Ian Campbell***. The medal is awarded annually to scientists whose careers are comparable to Campbell, who taught geology at the California Institute of Technology from 1931–1959, and then became California's state geologist. Campbell, AGI president in 1961, died in 1978.

Ian MacGregor has been appointed deputy director of the National Science Foundation's Division of Earth Sciences. He had been chief scientist in the Office of Scientific Ocean Drilling.

Albert Rango has been appointed chief of the Hydrology Laboratory at the Department of Agriculture's Agricultural Research Service in Beltsville, Md. The major research objectives of the laboratory are applying remote sensing to hydrology and water resources, investigating climate variability and its impact on soil moisture, and applying hydrological modeling to large areas and to pollution from nonpoint sources. A 10-year veteran of NASA's Goddard Space Flight Center, he was most recently head of Goddard's Hydrological Sciences Branch.

Henry Spall has been appointed associate chief of the Office of Scientific Publications of the U.S. Geological Survey National Center, Reston, Va.

In Memoriam

Jacob Otnes, national correspondent for Norway to the International Association of Hydrological Sciences (IAHS) and director of the Norwegian Hydrological Service, died January 17, 1983. A member of the Hydrology section, he joined AGU in 1961.

Leon Tison, Secretary General of the IAHS from 1948 to 1970 and the recipient of the first International Hydrology Prize in 1981, died on December 25, 1982.

Albert Rango

Books

AGU New Books

The Scientist and Engineer in Court
M. D. Bradley, 116 pp., softbound, 1983.
AGU members: $9.80; others: $14.

With increasing frequency, scientists and engineers are called on to serve as expert witnesses in court, yet few know their duties and fewer still know the procedures in a lawsuit. Many experts find the courtroom confusing, with proceedings that seem arcane and decisions that seem strange or even illogical. Outsiders are easily lost in the ceremony and drama of a lawsuit, especially if their expertise prepares them to deal more with facts than with values, with collaboration instead of advocacy, and with answers rather than settlements. Expert witnesses need preparation to understand what happens in lawsuits and to whom and why it happens.

Today courts are settling disputes with significant technical and scientific components and need expert witnesses to analyze scientific information. An expert's testimony helps a court accept scientific and technical information, process it for its substantive worth, and form it into a legal decision. But the expert needs more than technical skills. In order to function effectively as an expert witness, he also needs to understand the hidden dimensions of courtroom interactions, the tactics developed by lawyers in an adversarial proceeding, and the use of technical facts in legal decision making. Scientists and engineers can no longer afford the luxury of ignorance about the judicial process.

This volume clarifies the elements of a lawsuit, defines common legal terms, and offers a guide to the courtroom drama. Assuming that experts wish to be knowledgeable about the trial, it explains which evidence is admissible, the tactics of cross examination, and the need for effective communication with the judge or jury. It deals with the practical aspects of courtroom appearance and the calculation of witness fees. And it encourages experts to understand their role as learners in an evolving legal system. The message is simple: "Scientists have knowledge that courts find useful when deciding lawsuits; therefore, scientists should testify when asked as expert witnesses in court." By adding knowledge of the courtroom proceedings to an established technical or scientific expertise, the expert becomes a more valuable and effective witness.

Contents

Classified

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For further information, call toll free 800-424-2488 or, in the Washington, D. C., area, 462-6903.

POSITIONS AVAILABLE

Marine Research Associate II. Analyze and interpret time series of vertical acoustic travel time and bottom pressure. Prepare progress reports and scientific manuscripts on these results. Assist in planning experiments and participate in scientific cruises. Ph.D. in physical oceanography plus experience in computer programming with times series applications in FORTRAN. Submit application and resume by August 15, 1983, to: Dr. D.R. Watts, Marine Research Associate II Position, University of Rhode Island, P.O. Box 337, Kingston, Rhode Island 02881.

An affirmative action/equal opportunity employer m/f.

Research Positions for Mathematical Physicists. Applications are invited for several research positions at the Center for Studies of Nonlinear Dynamics, La Jolla Institute, beginning summer 1983. Current research involves work on nonlinear wave-wave interactions, acoustic, optical, and radio wave propagation in random media, and fluctuation phenomena in the statistical mechanics of chemical and geophysical systems. Physicists and applied mathematicians who are interested in working on problems of the above type should send resumes and arrange for three letters of recommendation to be sent to Dr. Stanley Flatte, Director, CSND, La Jolla Institute, 8950 Villa La Jolla Drive, Suite 2150, La Jolla, California 92037.

La Jolla Institute is an equal opportunity/affirmative action employer.

Assistant Professor/Crustal Reflection Seismology: University of Wyoming. A non-tenured position to conduct and direct research in reflection seismology is likely to become available on 1 August 1983 for a period of two years. Project involves processing and interpretation of COCORP and other deep crustal reflection data with Robert Burridge and Scott Smithson as the principal investigators.

Ph.D. or expected completion within six months required. Applicant must be experienced in processing and interpreting crustal reflection data. Responsibilities include supervising graduate students and conducting own research in processing and/or interpretation. Opportunity to become involved in an integrated approach to reflection seismology working with colleagues in electrical engineering and mathematics and to become involved in seismic data acquisition. Deadline for applications is July 1, 1983. Interested applicants send a resume and names of three references to:

Scott Smithson
Department of Geology and Geophysics
University of Wyoming
P.O. Box 3006, University Station
Laramie, WY 82071.

The University of Wyoming is an equal opportunity/affirmative action employer.

Geohydrologist. Lawrence Livermore National Laboratory currently has an opening for a Geohydrologist with an MS or Ph.D. degree or equivalent experience. You will support various programs including nuclear waste isolation and hydraulic fracturing of underground media. Assignment is a combination of field work and numerical modeling of porous or fracture flow of ground water utilizing existing computer codes or developing new codes to model ground water flow. Position requires a background in both numerical modeling and field geohydrology and applicants should have experience in application of numerical modeling to practical groundwater problems, including experience in dealing with contaminated groundwater.

LLNL is an applied science R&D facility operated by the University of California for the U.S. Department of Energy. We are located in Livermore, California, 40 miles east of San Francisco.

Send resume in strict confidence to Art Wong, Professional Employment Division, LAWRENCE LIVERMORE NATIONAL LABORATORY, P.O. Box 5510, KES-063, Livermore, CA 94550. U.S. Citizenship is required.

An equal opportunity employer M/F/H/V.

Research Associate/Petrography-Petrology. To join a research effort aimed at understanding the condensation history of the solar system by mineralogical, chemical, and isotopic studies of tiny inclusions in primitive meteorites. Applicant need not have previous experience with meteorites but should be a superb petrographer, skilled in the use of the SEM and electron probe. Successful candidate will be dedicated, productive, an effective communicator both orally and in writing, and will have Ph.D. in hand. Vacancy expected in late summer or early autumn 1983.

Send resume and names of three references to: L. Grossman, Department of the Geophysical Sciences, University of Chicago, 5734 S. Ellis Avenue, Chicago, IL 60637.

The University of Chicago is an equal opportunity/affirmative action employer.

Research Professor in Marine Geoscience/University of Rhode Island (Marine Geoscientist). The Graduate School of Oceanography invites applications for a research professorship in Marine Geoscience whose salary and rank are negotiable. Preference will be given to candidates who have clearly demonstrated abilities and interest in, but not necessarily limited to paleomagnetism. The position is funded by contracts and grants, however the research professor holds full faculty rights in addition to other benefits. The paleomagnetic facility at GSO is fully equipped, fully operational and oriented towards rapid measurement of large numbers of soil sedimentary samples. Applications are now open for the position which will become available about January 1, 1984.

Send letters of application, resume, and names and addresses of three professional references to: Roger L. Larson, Graduate School of Oceanography, University of Rhode Island, Narragansett, Rhode Island 02882.

An affirmative action/equal opportunity employer m/f.

Research Scientist/Space Plasma Physics, University of Iowa. A research position is available in the Department of Physics and Astronomy, The University of Iowa, for theoretical and interpretative studies of waves in space plasmas. Specific emphasis is on theoretical investigations of wave-particle interactions in planetary magnetospheres and in the solar wind. These investigations are to support the interpretation of data being obtained from spacecraft projects such as Dynamics Explorer, International Sun Earth Explorer and Voyager. The applicant must have a Ph.D. with good qualifications in plasma physics theory and should have some experience in the interpretation of space plasma physics data.

Send a resume and the names of three references familiar with the applicant's work to: D.A. Gurnett, Department of Physics and Astronomy, The University of Iowa, Iowa City, Iowa 52242, telephone 319-353-3527.

The University of Iowa is an affirmative action/equal opportunity employer.

Opportunities for Graduate Studies in the Atmospheric Sciences at the Georgia Institute of Technology. Openings are available for outstanding individuals seeking an M.S. or Ph.D. degree in graduate studies in the atmospheric sciences. For successful applicants, these positions include 1/2-time research assistantships with starting salaries ranging from $7,000 to $12,000/12 months, depending on the degree being sought and the student's qualifications. All tuition and fees are also covered by the institute.

The Atmospheric Sciences Program at Georgia Tech is part of the School of Geophysical Sciences and is uniquely structured academically in that major emphasis is given to three areas of atmospheric sciences, namely, Dynamic Meteorology, Physical Meteorology, and Atmospheric Chemistry. Major research efforts in which students are currently involved include studies in wind and solar power, climate modification, air pollution, uses of satellite meteorology, measurements of aerosols in the atmosphere, modeling of planetary circulations, mesoscale and boundary layer dynamics, development of laser instrumentation for the detection of atmospheric aerosols and gases, global airborne measurements of atmospheric trace gases, photochemical and gas kinetic studies of atmospheric transformations, studies of biogeochemical cycles, and one-, two- and three-dimensional chemical and dynamic modeling of the troposphere and stratosphere.

Students interested in being involved in these or other exciting Atmospheric Sciences projects at Georgia Tech should write for information to:

Dr. Douglas D. Davis
School of Geophysical Sciences
Georgia Institute of Technology
Atlanta, GA 30332.

Atmospheric Modeler/Programmer. Atmospheric and Environmental Research, Inc. has a staff position opening on a project to enhance the assimilation and forecast capabilities of an NWP spectral model by maximizing the model's use of satellite data. The position is for a recent PhD or experienced MS in meteorology or related field with an active interest in global numerical weather prediction. We are especially interested in individuals with expertise in one or more of the following areas: normal mode initialization, optimal interpolation, cloud parameterization and forecasting, boundary layer processes. Computer proficiency is a must—experience with Harris and/or CRAY hardware is desirable. Stimulating, academic-style research environment. Please send resume and names of references to: Dr. Lewis Kaplan, Principal Scientist, Atmospheric and Environmental Research, Inc., 840 Memorial Drive, Cambridge, MA 02139. Telephone 617-547-6207.

Argonne National Laboratory/Chemistry Division. An immediate postdoctoral position is available for atmospheric chemistry studies based on mass spectrometric analysis of the stable isotopic composition of atmospheric trace gases. Problems include source budgets and temporal variations of atmospheric trace gases and determination of atmospheric OH free radical concentrations using stable isotope tracers. Experimental techniques involve preparation of gas samples derived from trace gases using carrier gas train systems with cryogenic and chemical separation methods and precision mass spectrometric analysis. Send resume to: Mr. Walter McFall, Personnel Division, Box D-CHM-80, Argonne National Laboratory, 9700 South Cass Avenue, Argonne, Illinois 60439.

An equal opportunity employer.

Engineering Geosciences/U.S. Nuclear Regulatory Commission (NRC). The High-Level Waste Licensing Management Branch, Division of Waste Management, NRC, invites applications for excellent candidates to fill a variety of anticipated positions in the engineering geosciences.

The positions are related to the regulatory analysis of proposed deep geologic high-level radioactive waste repositories. Disciplines considered are: Hydrology, Geotechnology, Geochemistry, Hydrogeology, Materials Science, Geostatistics, and Statistical Risk Analysis. All applicants must have a strong computer modeling background and the equivalent of a Bachelor's or Master's degree in Engineering or Science. U.S. citizenship is required. Salaries range from GG-7 to GG-12 level, depending on qualifications.

Applications for these potential openings should be received by July 8, 1983. Please send resume or, preferably, SF-171 (Personnel Qualifications Statement) to:

Matthew J. Gordon
U.S. Nuclear Regulatory Commission
Mail Stop 623-SS
Washington, D.C. 20555.

The U.S. Nuclear Regulatory Commission is an equal opportunity employer.

Faculty Position for HREM Specialist/Arizona State University. A tenure-track faculty position at the Associate or Assistant Professor level is available at Arizona State University for a high-resolution electron microscopy specialist to work with the ASU Facility for High Resolution Electron Microscopy within the Center for Solid State Science.

The appointee will hold academic rank and will teach within the university department appropriate to his/her expertise. Qualifications include a doctoral degree in an appropriate area of science, a record of achievement and publication in high resolution electron microscopy and knowledge of related techniques such as microanalysis and microdiffraction. It is expected that the appointee will institute an active research program in electron microscopy or its applications in some area of solid state science using the instrumentation of the Facility and will serve as adviser to Facility users.

Send resume and arrange for three letters of recommendation to be sent to: J.M. Cowley, Center for Solid State Science, Arizona State University, Tempe, AZ 85287, before August 20, 1983.

Arizona State University is an equal opportunity/affirmative action employer.

Chairman—Department of Geological Sciences, Wright State University. The Department of Geological Sciences, invites applications for the position of chairman, to be appointed September 1984. We seek a dynamic individual with administrative talent and an appreciation for research and practice-related educational activities. Rank is at the full professor level and no restrictions have been placed on areas of specialization. The department is active with 12 faculty and an emphasis on professional practice, yet maintaining a firm commitment to basic research.

Send a letter of application, curriculum vitae and names of three references to:

Chairman, Search Committee
Department of Geological Sciences
Wright State University
Dayton, OH 45435.

Wright State University is an affirmative action/equal opportunity employer. Closing date for the position is October 31, 1983.

University of Colorado, Boulder, Geochemist Position. Geochemist with active research program, stable isotopes, radioactive isotopes, and/or trace elements is being sought for a joint appointment in the Department of Geological Sciences and the Cooperative Institute for Research in Environmental Sciences (CIRES) of the University of Colorado.

The one-half time position within the Department of Geological Sciences is tenure track at the assistant or associate professor level with a starting salary of $12,000—$15,000 for the academic year.

Teaching load will be half that of full-time faculty. The position within CIRES will be as a Fellow with appropriate office and laboratory space. One-half academic year salary will be guaranteed by CIRES for two years at the departmental rate, after which incumbent must generate his/her CIRES salary from external sources. Incumbent may augment salary further by generating three months of summer salary from contracts and grants, and consulting.

Applicants with experience, publications, and/or movable existing research equipment preferred. Preferred starting date would be January 1, 1984. Closing date for applications is October 1, 1983.

Applications should include statement of research and teaching interests, experience, a full vitae, and four letters of reference.

Apply to: Professor Charles Stern, Chairman, Geochemist Search Committee, Department of Geological Sciences, Campus Box 250, University of Colorado, Boulder, CO 80309.

The University of Colorado is an equal opportunity/affirmative action, Section 504 employer.

Temporary Faculty Position/UCLA. The Department of Earth and Space Sciences, UCLA, seeks applications for a temporary faculty position in the area of sedimentology, basin analysis, stratigraphy, and regional geology.

A Ph.D. or equivalent is required. There is no restriction as to the level. Duties will include undergraduate and graduate teaching, supervision of theses and dissertations, and development of a research program in the area of specialization. Field-based experience will be taken into consideration. The appointment will begin July 1, 1983, will be full-time nine-month, and will be renewable year-to-year. The department hopes to convert this position in 1984 or later, but has no assurance thereof. Send resume to:

Chairman
Department of Earth and Space Sciences
University of California
405 Hilgard Avenue
Los Angeles, CA 90024.

UCLA is an affirmative action equal opportunity employer.

Hydrogeologist. Converse Consultants is seeking a staff or project level hydrogeologist for investigations involving groundwater quality and supply, waste disposal, mineral and energy development and geotechnical projects. Las Vegas-based, will serve primarily in the southwestern U.S. Opportunity for interaction with an expanding staff of professionals in six regional offices. Excellent salary and advancement potential.

Minimum requirements are an advanced degree in geology plus two to five years experience involving such areas as aquifer testing and modeling, well and well field design, quantitative evaluation of groundwater flow, contractor supervision. Good communication skills are essential. Additional training or experience in geophysics and hydrology is desirable. Contact Dr. Robert F. Kaufmann, Principal Geologist, Converse Consultants, Inc., 4055 S. Spencer Street, Suite 120, Las Vegas, NV 89109.

Howard University/Graduate Faculty Position. The Department of Geology/Geography invites applications for a tenure-track position in geochemistry at rank of assistant or associate professor beginning August 1983. Position involves development of graduate research program at Master's level. Desired specialization includes environmental geochemistry, geochronology, isotope geology. Send letter of application, resume and names of three references to Dr. David Schwartzman, Department of Geology/Geography, Howard University, D.C. 20059.

STUDENT OPPORTUNITIES

Graduate Assistantships/Howard University. Howard University in Washington, D.C., offers a new graduate program for the M.S. degree in geoscience; made possible by a grant from the Gulf Oil Company. Areas of specialization are field geology/geophysics, geochemistry, and meteorology/hydrology with remote sensing. Some stipends and assistantships are available. Potential students should write to Dr. Eric Christofferson, Department of Geology and Geography, Howard University, Washington, D.C. 20059.

AGU

1983 VGP Award Nominations

Nominations are being sought for the 1983 VGP Award, which will be presented at the 1983 AGU Fall Meeting in San Francisco, December 5–10, 1983. The deadline for nominations is July 15.

The award is given for a single outstanding contribution to volcanology, geochemistry, or petrology made during the preceding 5 years. The contribution may be (1) a single outstanding paper published in any journal, (2) a series of papers that, when taken together, constitute an outstanding contribution, or (3) any other contribution that the Selection Committee considers worthy.

Any member of the scientific community is eligible for the award. Although the Selection Committee is encouraged to seek out scientists whose work has not been recognized by the receipt of other awards, this charge is not a restriction on the award. The award may be given to as many as five or as few as zero individuals in any calendar year. Multiple awards may either be shared or separate, as appropriate.

Nominations for the VGP Award may be made by any member of AGU. Each nomination must be accompanied by a written statement of the basis for the nomination. Copies of the contribution(s) for which the person is nominated should accompany the nomination statement if appropriate.

Nominations should be sent to the VGP President (Joseph V. Smith, Department of Geophysical Sciences, University of Chicago, Chicago, IL 60637), or the VGP President-Elect (G. Brent Dalrymple, U.S. Geological Survey, 345 Middlefield Road, MS 19, Menlo Park, CA 94025), or the VGP Secretary (Peter Lipman, U.S. Geological Survey, Denver Federal Center, MS 913, Denver, CO 80225) for forwarding to the Selection Committee

Meetings

Announcements

Flood Risk

A session on Flood Risk will be held at the AGU Fall Meeting in San Francisco, December 5–10, 1983.

During the last 5 years, research has produced many new and improved statistical techniques for estimating flood risk and various quantities of the flood-flow distribution at gauged sites. This session will review these new ideas as well as review *Bulletin 17*, as was revised in September 1981.

Topics should include advantages of regionalization, regional skewness, empirical Bayes estimators, probability weighted moments and the Wakeby distribution, measurement error and its impact, nonparametric procedures, and the use of historical flooding information. A companion session in the afternoon will examine the search for more physically based, extreme-value models in hydrology. The day will close with a special panel discussion chaired by John Schaake, Jr.

Mail one copy of your abstract to Jery R. Stedinger (Hollister Hall, Cornell University, Ithaca, NY 14853), the morning session organizer, by August 15, 1983, and the original and two copies of the abstract to AGU by September 14.

Watershed Models

A session on Treatment of Evapotranspiration, Soil Moisture Evolution, and Aquifer Recharge in Watershed Models will be held at the AGU Fall Meeting in San Francisco, December 5–10, 1983. Following the successful 1981 session, Impact of Richard's Equation, the Water in the Unsaturated Zone and Evapotranspiration Committee has decided to pursue the topic with a session even more specifically devoted to applications.

The session's invited and contributed papers will explore the manner in which the hydrologic phenomena of evapotranspiration, soil moisture evolution (including interflow), aquifer recharge, and aquifer return flows are treated in current (small) watershed and/or river basin models. Papers addressing the physical or conceptual basis for the treatment of the hydrologic components, the detailed structure of the mathematical models, the validity of the approaches taken, the laboratory or field verification of the approaches, the ease of calibration of the subsurface parameters, the experience in use of the models, etc., are welcome.

Prospective contributors should send three copies of an abstract of their paper as soon as possible and no later than July 29, 1983, to H. J. Morel-Seytoux, Department of Civil Engineering, Colorado State University, Fort Collins, CO 80523 (telephone 303-491-5448 or 491-8549). Please mail the original and two copies to Meetings, AGU, 2000 Florida Avenue, N.W., Washington, DC 20009, by September 14, 1983.

Conference

FUNDAMENTAL MAGNETOSPHERIC PROCESSES IN THE PLASMAPAUSE REGION

October 25–27, 1983

The University of Alabama in Huntsville
and
NASA/Marshall Space Flight Center
Huntsville, Alabama

Conveners: J. L. Horwitz and J. L. Green

This conference is designed for experimentalists and theorists concerned with wave and plasma processes in the vicinity of the plasmapause. Appropriate topics for papers to be presented will include: wave phenomena associated with the plasmapause; sources and loss of cold and warm plasmas near the plasmapause; plasmasphere filling; identification, structure, formation and dynamics of the plasmapause; relationship of plasmapause to other important magnetospheric boundaries. Attendance will be limited. Persons wishing to present papers should send an abstract (use convention for AGU meeting abstracts) to one of the conveners by July 9, 1983. Information on hotel accommodations will be provided on request.

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Geophysical Year

New Listings

The complete Geophysical Year last appeared in the May 31, 1983, *Eos*.

A boldface meeting title indicates sponsorship or cosponsorship by AGU.

Jan. 16–21, 1984 Penrose Conference on the Evolution of the Central Atlantic Ocean and Its Continental Margins, Giens, France. (J. Sougy, Laboratoire de Géologie Dynamique, LA CNRS no. 132, Faculté des Sciences de Saint Jérôme, 13397, Marseille Cedex 13, France; telephone: (91) 98 90 10, ext. 510.)

May 28–June 2, 1984 **12th International Congress on Irrigation and Drainage**, Fort Collins, Colo. Sponsor, the U.S. Committee on Irrigation, Drainage, and Flood Control. (U.S. Committee on Irrigation, Drainage and Flood Control, P.O. Box 15326, Denver, CO 80215.)

July 19–25, 1984 Symposium on Wave Breaking, Turbulent Mixing, and Radio Probing of the Ocean Surface, Sendai, Japan. (O. M. Phillips, Department of Earth and Planetary Sciences, Johns Hopkins University, Baltimore, MD 21218; telephone: 301-338-7034.)

GAP

Separates

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Aeronomy

0499 Aeronomy (General)
OBSERVATIONS OF THERMOSPHERIC DYNAMICS AT HIGH LATITUDES FROM GROUND AND SPACE
John W. Meriwether, Jr. (Space Physics Research Laboratory, University of Michigan, Ann Arbor, Michigan, 48109)
Comprehensive experimental investigations of the phenomenology of the F-region neutral wind and ion convection at high latitudes combined with improved theoretical modeling efforts have resulted in major advances in our current understanding of thermospheric dynamics of this region. We review the recent progress in this field. (Thermospheric dynamics, review).
Rad. Sci., Paper 3S0385

Exploration Geophysics

Hydrology

Meteorology

Oceanography

4713 Circulation (Equatorial Pacific)
INTERANNUAL VARIABILITY OF THE EQUATORIAL PACIFIC — REVISITED
A. J. Busalacchi (Goddard Laboratory for Atmospheric Sciences, NASA/Goddard Space Flight Center, Greenbelt, Maryland 20771), K. Takeuchi and J. J. O'Brien
A linear numerical model forced by monthly ship-based wind estimates used to study the interannual response of the tropical Pacific Ocean for 1961-1979 (Busalacchi and O'Brien, 1981) is extended through December, 1978. The additional eight years include the 1972 and 1976 Los Ninos and the aborted event of 1975. Model pycnocline variations at several locations are compared with observed sea level fluctuations. El Nino events are depicted as periods when the pycnocline is persistently deep along the eastern boundary. Remotely forced equatorial Kelvin waves are responsible for this response. The character of each simulated El Nino is strongly dependent on the relation between zonal wind stress changes in the western and central equatorial Pacific. There are important differences in the location and timing of the wind changes associated with each El Nino. During the 1970's the easterlies in the central equatorial Pacific had more of an active role in the evolution of El Nino than in the previous decade. In the western tropical Pacific a rapid shoaling of the pycnocline during each El Nino is caused by westward-propagating Rossby waves. Interannual pycnocline displacements in the central equatorial Pacific are determined by the superposition of Kelvin waves excited to the west and first meridional mode Rossby waves generated to the east. (El Nino, remote forcing, equatorial waves)
J. Geophys. Res., Green, Paper 3C0770

4730 Internal Waves
TIDAL PHASE OF INTERNAL-WAVE GENERATION
C. Sawyer
NOAA, ERL, Pacific Marine Environmental Laboratory Seattle, Washington 98105
Presently working at the High Altitude Observatory Boulder, Colorado 80397
The tidal phase at which ocean internal waves are generated is examined using two sets of data. The first data set, consisting of 81 time series of internal-wave packets located with respect to the continental shelf edge on satellite images, clearly indicates generation near flood tide. Observed location of wave packets confirms the expectation based on theory that internal-wave generation occurs at the shelf edge. Wave speed is determined from separation of packet pairs presumed to be generated at successive tides. This speed, with distance of the nearest packet from the shelf edge, determines the time of generation. Comparison to predicted tidal phase shows that all estimated generation times are within 3.8 hours of flood, and only one of the 21 values is closer to ebb than to flood. The mean value of generation time relative to maximum flood is -0.2 hours and the median value is -0.1 hour. The images cover all phases of the tidal cycle, and the result appears to be representative for shelf generation.
In the second data set, observations of thermal oscillations shoreward of a sill can be modelled either as generated shortly after ebb tide on the seaward side of the sill, or slightly before flood, on the shoreward side. The absence to date of observations of evidence of internal waves over the sill or seaward of the sill, points to flood generation at the sill as well as at the shelf. (Internal waves, tidal generation, satellite imagery).
J. Geophys. Res., Green, Paper 3C1288

DELEGATES

18th General Assembly of IUGG

U.S. scientists planning to attend the 18th General Assembly of IUGG, Hamburg, West Germany, August 15–27, 1983, should notify A. F. Spilhaus, Jr., Secretary, U.S. National Committee, 2000 Florida Avenue, N.W., Washington, D.C. 20009, and indicate in which IUGG association they propose to participate so that they can be officially designated as delegates from the United States.

Particles and Fields—Ionosphere

Pi 2 magnetic pulsations are frequently observed at synchronous orbit by the UCLA fluxgate magnetometer on ATS-6. Events that occurred in September 1974 have been studied using digital power spectra and coherency analysis to determine wave characteristics. From examination of wave form and spectral analysis, these Pi 2 events can be divided into three types. The first is a superposition of a 100-second oscillation and a large-amplitude, higher-frequency Pi 1 activity. The second is a 100-second wave unaccompanied by Pi 1.

Particles and Fields—Magnetosphere

Physical Properties of Rocks

Planetology

Seismology

Solar Physics, Astrophysics, and Astronomy